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TENT COOPERATION TRE. /

PCT

NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis.1 and
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

ÖRTENBLAD, Bertil
Noréns Patentbyrå AB
Box 10198
S-100 55 Stockholm
SUÈDE

Date of mailing (day/month/year) 16 October 2000 (16.10.00)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 990034PC	
International application No. PCT/SE00/00292	International filing date (day/month/year) 15 February 2000 (15.02.00)

1. The following indications appeared on record concerning:		
<input checked="" type="checkbox"/> the applicant	<input type="checkbox"/> the inventor	<input type="checkbox"/> the agent <input type="checkbox"/> the common representative
Name and Address ALTITUN AB Isafjordsgatan 9 S-164 40 Kista Sweden	State of Nationality SE	State of Residence SE
	Telephone No.	
	Facsimile No.	
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2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:		
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Name and Address ALTITUN AB Box 911 S-175 29 Järfälla Sweden	State of Nationality SE	State of Residence SE
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3. Further observations, if necessary:		
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The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer A. Karkachi Telephone No.: (41-22) 338.83.38
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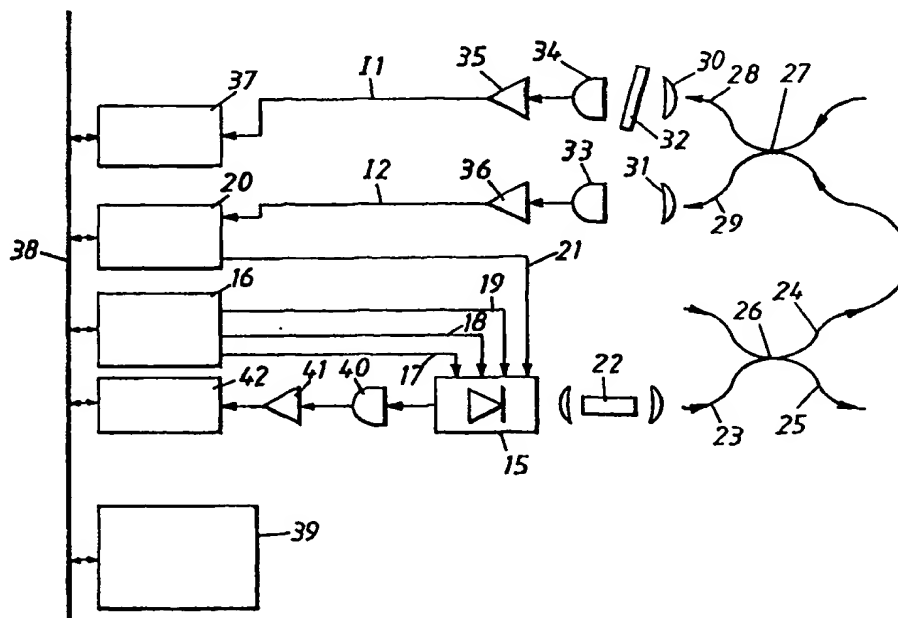
With international search report.

(54) Title: A METHOD OF CHARACTERISING A TUNEABLE LASER

(57) Abstract

A method of evaluating a tuneable laser (15) and determining suitable laser operation points, wherein said laser includes two or more tuneable sections in which injected currents can be varied, of which sections at least one is a reflector section and one is a phase section. The invention is characterised by leading part of the light emitted by the laser (15) to an arrangement which includes a Fabry-Perot filter (32) and a first detector (33) and a second detector (34), said detectors being adapted to measure the power of the laser and to deliver a corresponding detector signal (I1, I2); arranging the detectors relative to the Fabry-Perot filter so that the detector signals (I1, I2) will contain information relating at least to the wavelength of the detected light; sweeping the currents through the tuning sections (17, 18, 19) such as to pass

through different current combinations; measuring the ratio between the two detector signals (I1, I2) during said sweep, wherein the reflector current (17) is the inner sweep variable which is swept in one direction and then in an opposite direction back to its start value; and storing the control combination for said tuning currents when the ratio between the detector signals (I1, I2) lies within a predetermined range signifying that the emitted light lies within one of a number of wavelengths given by the Fabry-Perot filter (32) and said ratio lies within said predetermined range for a given reflector current in both sweep directions of said reflector current.



PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

REC'D 23 MAR 2001

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Applicant's or agent's file reference 990034PC	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/SE00/00292	International filing date (day/month/year) 15.02.2000	Priority date (day/month/year) 17.02.1999
International Patent Classification (IPC) or national classification and IPC ⁷ H 01 S 3/133, H 01 S 3/10, H 01 L 33/00		
Applicant Altitun AB et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.
- ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).
- These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand 03.08.2000	Date of completion of this report 07.03.2001
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. 08-667 72 88	Authorized officer Måns Marklund/MN Telephone No. 08-782 25 00

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE00/00292

I. Basis of the report

1. With regard to the **elements** of the international application:*

- ☒ the international application as originally filed
- ☐ the description: _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the claims: _____, as originally filed
 pages _____, as amended (together with any statement) under article 19
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the drawings: _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the sequence listing part of the description: _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item. These elements were available or furnished to this Authority in the following language _____ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages _____
- ☐ the claims, Nos. _____
- ☐ the drawings, sheet/fig _____

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

** Any replacement sheet containing such amendments must be referred to under item I and annexed to this report.

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V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**1. Statement**

Novelty (N)	Claims	<u>1-6</u>	YES
	Claims		NO
Inventive step (IS)	Claims	<u>1-6</u>	YES
	Claims		NO
Industrial applicability (IA)	Claims	<u>1-6</u>	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

The invention relates to a method of evaluating a semiconductor tunable laser, including two or more sections, said sections including at least a reflector section and a phase section. Current is injected in each section for controlling different output parameters such as wavelength and output power. A problem in controlling the laser parameters arises due to hysteresis i.e. different output parameters occurs at the same current injection values depending on earlier variations of the current combinations. In order to overcome this problem, the method according to the invention, part of the light emitted is lead to an arrangement including a Fabry-Perot filter and two detectors. The detectors measure the power and delivers corresponding detector signals. The detectors are arranged relative to the Fabry-Perot filter so that the detector signals contain information relating to the wavelength of the detected light. The currents through the sections of the laser are swept. When the ratio between the detector signals signifies that the emitted light lies within one of a number of wavelengths, given by the Fabry-Perot filter, for a given current through the reflector section in both sweep directions, the combination is stored.

Documents cited in the International Search Report:

D1: EP 0529732 A1
D2: EP 0774684 A2
D3: GB 2163286 A
D4: US 4792956 A
D5: HECHT, "OPTICS", Addison Wesley, 1998

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

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Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: V

Through D1 the problem of hysteresis in tunable lasers is known. In order to avoid frequency jumps due to mode hopping, the frequency jumps presenting hysteresis, D1 suggests giving the control currents a certain disproportional relation by a control unit. In page 5 of document D1 it is suggested that the tunable laser is a Distributed Bragg Reflector (DBR) laser, comprising three sections: Amplifying-, Transmission- and Bragg-section. The relation of the currents injected to the transmission and Bragg-sections is disproportional in order to avoid different oscillation modes due to hysteresis.

D2 describes a way of sweeping the reflector current of a two section laser, comprising a amplifying-section and a DBR-section. By measuring the wavelength the relation between injected reflector current and wavelength can be established. D2 also mentions the problem of mode hopping.

D3 describes a way of controlling the output power and stabilizing the wavelength of a semiconductor laser.

D4 describes a control unit for controlling the wavelength and intensity of a laser diode.

D5 describes a Fabry-Perot filter, page 422.

Both D1 and D2 is primarily concerned in how to operate the laser, once the current combinations that give rise to mode hopping in a hysteresis fashion, is known. This problem is however not the same problem solved in the present invention. The invention according to claim 1 differs from what is known from D1 and D2 in that it gives a method for detecting and storing the current combinations giving rise to mode hopping free operation of the laser.

D3 and D4 describe controlling of non-tunable lasers and are only considered defining the general state of the art.

D5 states the general state of the art of one component of the arrangement and is not considered relevant.

In the light of the aforementioned:

-The invention claimed in claims 1 - 6 is novel (N), is considered to involve an inventive step (IS) and is considered to have industrial applicability (IA).

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ART 34 AMDT

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for each wavelength included in a channel plane which contains desired wavelengths and exhibits a transmission that deviates therefrom with respect to other wavelengths.

5 3. A method according to Claim 1 or 2, characterised by delivering the signal from one detector (33) at the front mirror of the laser to a power regulating circuit (20) which is adapted to control the laser (15) to emit light with a constant power from the front mirror.

10 4. A method according to Claim 1, 2 or 3, characterised by causing a monitor diode (40) placed on the side of the laser (15) opposite to that side on which the first (32) and the second (33) detectors are placed to measure the light emitted by the laser; and adjusting one or more of the tuning currents so as to minimize the ratio between the power of the rearwardly emitted light and the power of the forwardly emitted light, therewith optimising an operation point for the laser (15).

20 5. A method according to Claim 1, 2, 3 or 4, characterised by sweeping one or more other tuning currents to sections that exhibit an hysteresis effect, excluding the reflector current, so as to determine whether or not hysteresis occurs in a contemplated operation point.

25 6. A method according to Claim 1, 2, 3, 4 or 5, characterised by measuring the wavelength transmitted by the laser (15) in a number of the possible operation points taken out until one operation point has been obtained for each desired wavelength, and storing the control combination for each operation point.

30 7. A method according to Claim 1, 2, 3 or 4, characterised by sweeping one or more other tuning currents to sections that exhibit an hysteresis effect, and

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1
A METHOD OF CHARACTERISING A TUNEABLE LASER

The present invention relates to a method of enabling a tuneable laser to be characterised quickly.

5

The method can be applied for evaluating and selecting lasers with respect to emitted wavelength and to find good operation points systematically.

10 Tuneable semiconductor lasers have a number of different sections through which current is injected, typically three or four such sections. The wavelength, power and mode purity of the lasers can be controlled by adjusting the current injected into the various sections. Mode purity implies that
15 the laser shall be in an operation point, i.e. at a distance from a combination of the drive currents where so-called mode jumps take place and where lasering is stable and side mode suppression is high.

20 In the case of telecommunications applications, it is necessary that the laser is able to retain its wavelength to a very high degree of accuracy and over very long periods of time, after having set the drive currents and the temperature. A typical accuracy in this respect is 0.1
25 nanometer and a typical time period is 20 years.

In order to be able to control the laser, it is necessary to map the behaviour of the laser as a function of the various drive currents. This is necessary prior to using the laser
30 after its manufacture.

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Mapping of the behaviour of a laser is normally effected by connecting the laser to different measuring instruments and then varying the drive currents systematically. Such instruments are normally power meters, optical spectrum analysers for measuring wavelength and sidemode suppression, and line width measuring devices. This laser measuring process enables all of these parameters to be fully mapped as a function of all different drive currents.

One problem is that lasers exhibit an hysteresis. As a result of these hystereses, the laser will deliver different output signals in the form of power and wavelength in respect of a given drive current set-up, i.e. with respect to a given operation point, depending on the path through which the laser has passed with respect to the change in said drive currents in order to arrive at the working point in question. Thus, this means that a given drive current set-up will not unequivocally give the expected wavelength or power.

In the case of a tuneable laser, the wavelength of the emitted light is determined mainly by the current or voltage across the tuning sections. The power emitted is controlled by current to the gain section of the laser or by the current across said section.

When characterising a laser, all of the possible control combinations afforded by the tuning sections, or a subset of said sections, are investigated. During the characterising process, the emitted light is studied with respect to wavelength and sidemode suppression and controlling the gain section with regard to power adjustment.

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The enormous number of possible control combinations, typically tens of billions of which fewer than a hundred shall be selected, makes total mapping of the laser impossible in view of the large amount of data generated.

5

The present invention solves this problem and provides a method of quickly sorting away control combinations that do not result in correct wavelengths.

10 The present invention also relates to a method of evaluating a tuneable laser and determining suitable laser operation points for a laser that includes two or more tuneable sections in which injected current can be varied and of which at least one is a reflector section and one is a phase section, wherein said method is characterised by leading part of the light emitted by the laser to an arrangement that includes a Fabry-Perot filter and a first and a second detector, said detectors being adapted to measure the power of the light and to deliver a corresponding detector signal; 15 arranging the detectors relative to the Fabry-Perot filter such that the data signals will contain information relating at least to the wavelength of the detected light; sweeping the currents through the tuning sections so as to pass through different current combinations; measuring the ratio between the two detector signals during said sweeps; sweeping 20 the reflector current in the inner sweep variable in one direction and then in the opposite direction back to its start value; and storing the control combination for the tuning currents when the ratio between the detector signals lies within a predetermined range that indicates that the light emitted lies within one of a number of wavelengths given by the Fabry-Perot filter and said ratio lies within 25 30

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said predetermined range for a given reflector current in both sweep directions of said current.

The invention will now be described in more detail with reference to exemplifying embodiments thereof and also with reference to the accompanying drawings, in which

- Figure 1 is a perspective, partially cut-away view of a DBR laser;

- Figure 2 is a sectional view of a tuneable Grating Coupled Sampled Reflector (GCSR) laser;

- Figure 3 is a sectional view of a Sampled Grating DBR laser; and

- Figure 4 is a schematic block diagram illustrating an arrangement which is used in accordance with the invention.

Shown in Figure 1 is a DBR laser which includes three sections, namely a Bragg reflector 1, a phase section 2 and a gain section 3. Each section is controlled by injecting current into respective sections through respective electric conductors 4, 5, 6.

Figure 2 is a sectional view of a tuneable Grating Coupled Sampled Reflector (GCSR) laser. Such a laser includes four sections, i.e. a Bragg reflector 7, a phase section 8, a coupler 9 and a gain section 10. Each of the sections is controlled by injecting current into respective sections.

Figure 3 is a sectional view of a Sampled Grating DBR laser that also includes four sections 11, 12, 13, 14, of which sections 11 and 14 are Bragg reflectors, section 13 is the phase section, and section 12 is the gain section.

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These three laser types are common, although other types of lasers exist.

Although the invention is described below essentially with reference to a GCSR laser according to Figure 2, it will be understood that the invention is not too restricted to any particular type of tuneable semiconductor laser, but can be applied correspondingly with tuneable lasers other than those illustrated by way of example in the drawings.

The present invention relates to a method of evaluating tuneable lasers and determining suitable laser operation points. The laser may thus contain two or more tuneable sections in which injected current can be varied in a known manner. The laser is of the kind which includes at least one reflector section and one phase section.

Figure 4 is a block diagram which illustrates an arrangement used in accordance with the present invention. The reference numeral 15 identifies a GCSR laser, while the reference numeral 16 identifies current generators for injecting current into the reflector section, the phase section and the coupler section respectively of said laser, through respective conductors 17, 18 and 19. The power of the laser is controlled to its gain section by means of a power regulating circuit 20, via a conductor 21.

The laser emits light from the front mirror to a light conductor 23, for instance light fibre, via a lens pack 22. This light conductor leads the light to a light splitter or divider 26 which switches part of the light to another light conductor 24. The remainder of the light is led further in

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the conductor 25. The light splitter 26 switches, e.g., 10% of the light from the conductor 23 to the conductor 24.

5 The light conductor 24 leads the light to a second light splitter or divider 27 which functions to divide the light equally between two light conductors 28, 29. A lens 30 and a lens 31 are disposed at respective ends of the light conductors. A Fabry-Perot filter 32 is provided in the beam path downstream of the lens 30. The filter 32 is well known and will not therefore be described in more detail in this document. Fabry-Perot filters can be designed to exhibit a certain light transmission solely for certain wavelengths, normally wavelengths that are multiples of a given wavelength. The Fabry-Perot filter exhibits a deviating lower or higher transmission at other wavelengths.

10 A first detector 33 is provided downstream of the lens 31, and a second detector 34 is provided downstream of the Fabry-Perot filter. The detectors 33, 34 function to measure the power of the light and to deliver a corresponding detector signal to an A/D converter 37, via a respective amplifier 35, 36.

20 The A/D converter 37, the power regulating circuit 20 and the current generators 16 are all connected to a microprocessor 39 via a data bus 38. The microprocessor is adapted to control the current generators and the power regulating circuit in a desired and a well known manner, in response to the signals from the A/D converter 37 and the power regulating circuit 20.

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According to the invention, part of the forwardly emitted light is thus conducted to the first detector 31 and also to the second detector 34, via the Fabry-Perot filter 32.

5 According to the invention, the currents are swept through the tuning sections 18, 19, 21 such as to pass through different current combinations. The ratio between the two detector signals I1 and I2 is measured during said sweeps.

10 When sweeping the currents through the tuning sections, the reflector current is the inner sweep variable. It is meant by this that the reflector current is swept for different combinations of other tuning currents while holding said currents constant. The reflector current is swept first in
15 one direction and then in the opposite direction, back to its start value. For instance, the reflector current is swept from a zero value and up to its maximum value and then down to zero again.

20 By current control in the present document is meant that the current through the sections is controlled by current generators or, alternatively, by controlling the voltage across the sections.

25 In the case of the Figure 4 embodiment, the first detector, the second detector and the Fabry-Perot filter are placed in the proximity of the front mirror of the laser. Alternatively, the components may equally as well be placed in the proximity of the rear mirror of the laser, in which
30 case light emitted from the rear mirror of said laser is used to determine the wavelength.

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The Fabry-Perot filter and the first and the second detector may be arranged relative to one another in a manner different to that shown in Figure 4, so as to detect at least wavelengths. The first and the second detector may be arranged to measure light transmitted through the Fabry-Perot filter and/or light reflected towards the Fabry-Perot filter, such as to detect wavelengths.

The hysteresis effect exhibited by lasers causes the power output of the laser in respect of certain reflector currents, with otherwise constant conditions, to be different due to the reflector current having taken its existing value by virtue of the reflector current having increased to said value or having decreased from a higher value. The wavelength is also influenced by the hysteresis effect. Such operation points as those which lie in the regions of hysteresis with respect to the reflector current, or with respect to other tuning currents for those sections that exhibit hysteresis, are non-preferred operation points for a laser in operation.

Communication lasers shall be adapted to operate at certain given wavelengths that are included in a so-called channel plane, where each channel corresponds to a well defined wavelength. According to the invention, the Fabry-Perot filter 32 is adapted to have a certain given transmission for each wavelength included in the channel plane.

When the ratio between the detector signals I_1/I_2 from the detectors 32, 33 lies within a predetermined range implying that the emitted light lies within one of a number of wavelengths given by the Fabry-Perot filter and said ratio I_1/I_2 lies within said range for a given reflector current in

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both sweep directions of the reflector current, the control combination for the tuning currents is stored in accordance with the invention.

- 5 This range is given by the permitted channel width in the channel plane.

10 These control combinations thus fulfil the criteria that will give desired wavelengths and not result in any hysteresis effect.

15 In certain cases, it is preferred that one or more other tuneable currents to sections that exhibit an hysteresis effect, excluding the reflector current, are swept so as to determine whether or not hysteresis occurs in a contemplated operation point.

20 According to one preferred embodiment, the signal I2 is delivered from the first detector 33 to the power regulating circuit 20. The regulating circuit is adapted to control the laser so that said laser will emit light at a constant power. This enables the ratio I1/I2 to be followed very easily in determining possible operation points.

25 According to another preferred embodiment of the invention, a monitored diode is placed on the side of the laser opposite to that side on which the first and the second detectors are placed, said monitor diode being caused to measure the light emitted by the laser. The detector signal is led through an
30 amplifier 41 to an A/D converter 42, whose output signal is delivered to the microprocessor 39. In this embodiment, one or more of the tuneable currents is chosen so as to minimise

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the ratio between the power of the rearwardly emitted light and the power of the forwardly emitted light, thereby enabling an optimum operation point for a channel to be selected from said possible operation points.

5

The monitor diode 40 is placed adjacent the rear mirror of the laser in the Figure 4 embodiment.

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It is highly preferred with a number of the possible operation points taken out to measure the wavelength emitted by the laser until an operation point has been obtained with each desired wavelength, wherewith the control combination for each operation point is stored. Thus, one control combination for each channel in the channel plane will be stored in the memory of the microprocessor.

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It will be evident from the foregoing that the use of a Fabry-Perot filter enables all those control combinations that do not fulfil the criterion that the ratio between the currents I_1/I_2 shall lie within a certain given range to be sorted out. Moreover, it is sufficient for communications purposes to identify one control combination for each wavelength in the channel plane that lies in a region in which the laser exhibits no hysteresis.

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The present invention thus solves the problem mentioned in the introduction.

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Although different embodiments have been described, and therewith in respect of a GCSR laser, it will be obvious that the structural design of the described arrangement can be

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varied while achieving the same result. The invention can also be applied to lasers of a type other than GCSR lasers.

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It will therefore be understood that the present invention is not restricted to the aforescribed and illustrated exemplifying embodiments thereof and that variations can be made within the scope of the following Claims.

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CLAIMS

1. A method of evaluating a tuneable laser (15) and determining suitable laser operation points, wherein said
5 laser includes two or more tuneable sections in which injected currents can be varied, of which sections at least one is a reflector section and one is a phase section, characterised by leading part of the light emitted by the laser (15) to an arrangement which includes a Fabry-Perot
10 filter (32) and a first detector (33) and a second detector (34), said detectors being adapted to measure the power of the laser and to deliver a corresponding detector signal (I1, I2); arranging the detectors relative to the Fabry-Perot filter so that the detector signals (I1, I2) will contain
15 information relating at least to the wavelength of the detected light; sweeping the currents through the tuning sections (17, 18, 19) such as to pass through different current combinations; measuring the ratio between the two detector signals (I1, I2) during said sweep, wherein the
20 reflector current (17) is the inner sweep variable which is swept in one direction and then in an opposite direction back to its start value; and storing the control combination for said tuning currents when the ratio between the detector signals (I1, I2) lies within a predetermined range signifying
25 that the emitted light lies within one of a number of wavelengths given by the Fabry-Perot filter (32) and said ratio lies within said predetermined range for a given reflector current in both sweep directions of said reflector
30 current.

2. A method according to Claim 1, characterised in that the Fabry-Perot filter (32) exhibits a certain transmission